11.0 PLANT SYSTEMS

11.3 MIXED OXIDE PROCESS SYSTEM DESCRIPTION AND REVIEW

11.3.1 CONDUCT OF REVIEW

This section of the revised Draft Safety Evaluation Report (DSER) contains the staff's review of the Mixed Oxide (MOX) Process (MP) safety described by the applicant in Chapter 11.2 of the revised Construction Authorization Request (CAR), with supporting process safety information from Chapters 5, 8, and 11 of the revised CAR (Reference 11.3.3.7). The objective of this review is to determine whether the chemical process safety principal structures, systems, and components (PSSCs) and their design bases identified by the applicant provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents. The staff evaluated the information provided by the applicant for chemical process safety by reviewing Chapter 8 of the revised CAR, other sections of the revised CAR, supplementary information provided by the applicant, and relevant documents available at the applicant's offices but not submitted by the applicant. The staff also reviewed technical literature as necessary to understand the process and safety requirements. The review of MP safety design bases and strategies was closely coordinated with the review of the radiation and chemical safety aspects of accident sequences described in the Safety Assessment of the Design Bases (see Chapter 5.0 of this revised DSER), the review of fire safety aspects (see Chapter 7.0 of this revised DSER), and the review of plant systems (see Chapter 11.0 of this revised DSER).

The staff reviewed how aqueous polishing process and chemistry information in the revised CAR addresses or relates to the following regulations:

- Section 70.23(b) of 10 CFR states, as a prerequisite to construction approval, that the design bases of the PSSCs and the quality assurance program be found to provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

- Section 70.64 of 10 CFR requires that baseline design criteria (BDC) and defense-in-depth practices be incorporated into the design of new facilities or new processes at existing facilities. With respect to chemical protection, 10 CFR 70.64(a)(5) requires that the Mixed Oxide Fuel Fabrication Facility (MFFF or the facility) design provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from licensed material. Related to chemical protection, 10 CFR 70.64(a)(3) requires that the facility design provide for adequate protection against fires and explosions, such as those that could be initiated by or involve chemicals at the proposed facility.

The review for this construction approval focused on the design basis of chemical process safety systems, their components, and other related information. For each chemical process safety system, the staff reviewed information provided by the applicant for the safety function, system description, and safety analysis. The review also encompassed proposed design basis considerations such as redundancy, independence, reliability, and quality. The staff used Section 8 of NUREG-1718, "Standard Review Plan (SRP) for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility," (Reference 11.3.3.9), as guidance in performing the review. As stated on page 8.0-2 of NUREG-1718, information contained in the application should be of sufficient quality and detail to allow for an independent review, assessment, and verification by the NRC reviewers.

At U.S. Nuclear Regulatory Commission (NRC) licensed facilities, as stated in the NRC "Memorandum of Understanding between the Nuclear Regulatory Commission and the Occupational Safety and Health Administration: Worker Protection at NRC-Licensed Facilities," (Federal Register. Vol. 53, No. 210, October 31, 1998, pp. 43950-43951), the NRC oversees chemical safety issues related to (1) radiation risk produced by radioactive materials; (2) chemical risk produced by radioactive materials; and (3) plant conditions that affect the safety and safe handling of radioactive materials, and, thus, represent an increased radiation risk to workers. The NRC does not oversee facility conditions that result in an occupational risk but do not affect the safe use of licensed radioactive material.

The NRC staff reviewed the revised CAR submitted by the applicant for the following areas applicable to process safety at the construction approval stage and consistent with the level of design (NUREG-1718, page 8.0-8):

- MP Description.
- Hazardous Chemicals and Potential Interactions Affecting Licensed Materials.
- MP Chemical Accident Sequences.
- MP Chemical Accident Consequences.
- MP Safety Controls.

Additional documentation from the applicant and the literature was reviewed as necessary to understand the process and safety requirements. In addition, the revised CAR incorporates the BDC of 10 CFR 70.64(a) into the design and operations of the proposed facility (see revised CAR Section 5.5.5.4, page 5.5-67), and applicable sections of the revised CAR are intended to demonstrate compliance with these BDCs.

The staff utilized the guidance provided by Chapter 8.0 of NUREG-1718 for assistance in determining the compliance of the application with the regulation. The evaluation used the guidance of Section 8.4 of NUREG-1718 for determining acceptance with 10 CFR Part 70, consistent with a construction approval stage and the level of the design. The evaluation is summarized in the sections that follow.

11.3.1.1 System Description of the MP Process

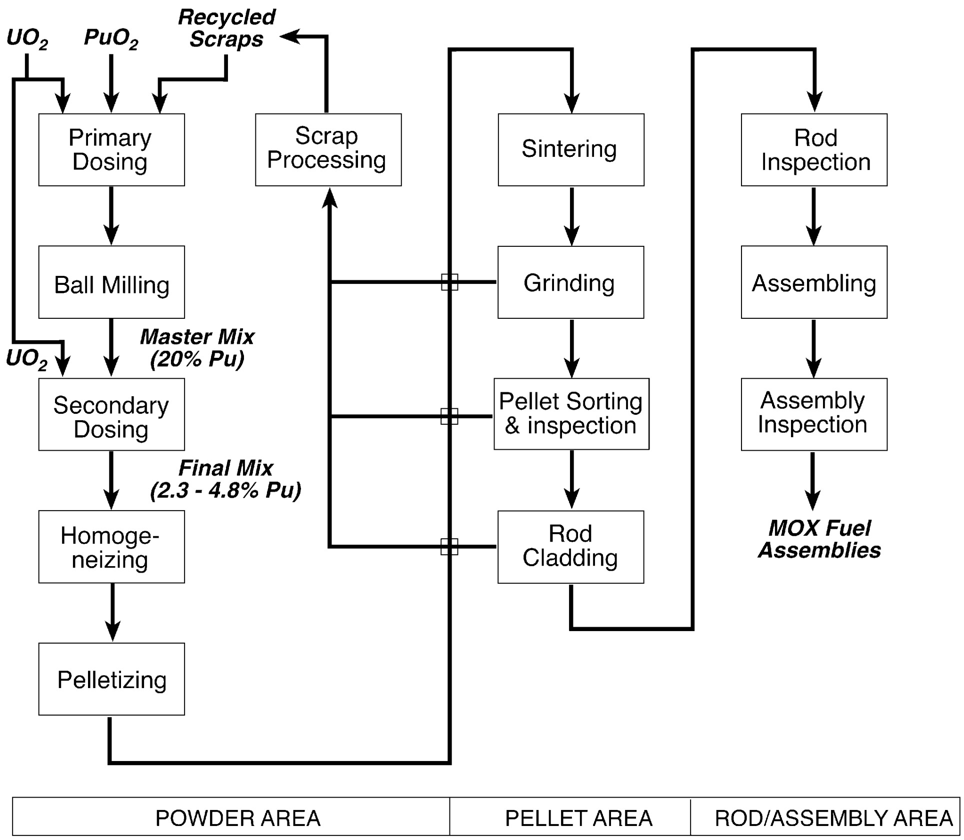
This section provides a description and overview of the MP, including design, operational, and process flow information. This information is provided to support the hazard and accident analysis provided in Chapter 5, as well as to assist in understanding the overall design and function of the MOX Process.

The MP Area receives polished PuO_2 from the aqueous polishing (AP) process, depleted UO_2 (i.e., uranium depleted in the uranium-235 isotope below the natural assay of 0.71 percent), and the required components for assembling light-water reactor (LWR) MOX assemblies. The process mixes the plutonium and uranium dioxides to form MOX fuel pellets. The pellets are loaded into fuel rods, which are then assembled into MOX fuel assemblies for use in commercial reactors. The MP Area is designed to process up to 70 metric tons heavy metal (MTHM) (uranium plus plutonium) annually. The safety functions of the PSSCs associated with the MP process are discussed in Chapter 5 of the revised CAR.

The facility uses the advanced micronized master blend (A-MIMAS) process for the manufacture of MOX fuel assemblies. A-MIMAS uses a two-step, dry mixing process. In the first step, the PuO_2 powder is mixed with depleted UO_2 and recycled scrap powder to form a primary blend (master blend) with approximately 20 percent PuO_2 content of the total mass. This mix is then micronized - reduced in particle size into a very fine powder. In the second step, the primary blend is forced through a sieve and poured into a jar and mixed with more depleted UO_2 and scrap powder to obtain the final blend with the specified plutonium content (typically around 6 percent of the heavy metal content). The two-step mixing process is used to ensure a consistent product.

The MP process consists of 38 process units or systems divided into five areas corresponding to the different segments of the process (see Figure 11.3-1).

Figure 11.3-1. Overview of MP



Receiving Area - This area includes truck unloading, PuO_2 container handling, counting, and storage before and after transfer to the AP line. The function of the Receiving Area is to receive, unload, and store PuO_2 and UO_2 powder. The Receiving Area is comprised of the following discrete units:

- UO_2 Receiving and Storage Unit.
- UO_2 Drum Emptying Unit.
- PuO_2 Receiving Unit
- PuO_2 3013 Storage Unit.
- PuO_2 Buffer Storage Unit.

Powder Area - This area has equipment for dosing MOX powder at the specified plutonium content in two steps for homogenizing and for pelletizing. The Powder Area receives UO_2 and PuO_2 powders and produces a mixture of specific plutonium content suitable for the production of MOX fuel pellets. The Powder Area is composed of the following units:

- PuO_2 Can Receiving and Emptying Unit.
- Primary Dosing Unit.
- Primary Blend Ball Milling Unit.
- Final Dosing Unit.
- Homogenization and Pelletizing Unit.
- Scrap Processing Unit.
- Scrap Ball Milling Unit.
- Powder Auxiliary Unit.
- Jar Storage and Handling Unit.

Pellet Process Area - In this area, MOX pellets are sintered, ground, and sorted. The function of the Pellet Process Area is to receive, store, process, and handle fuel pellets. The Pellet Process Area is composed of the following units:

- Green Pellet Storage Unit.
- Sintering Units.
- Sintered Pellet Storage Unit.
- Grinding Units.
- Ground and Sorted Pellet Storage Unit.
- Pellet Inspection and Sorting Units.
- Quality Control and Manual Sorting Units.
- Scrap Box Loading Unit.
- Pellet Repackaging Unit.
- Scrap Pellet Storage Unit.
- Pellet Handing Unit.

Fuel Rod Process Area - In this area, pellets are loaded into rods and the rods are inspected. The function of the Fuel Rod Process Area is to assemble, inspect, and store fuel rods. The Fuel Rod Process Area is composed of the following units:

- Rod Cladding and Decontamination Units.
- Rod Tray Loading Unit.
- Rod Storage Unit.
- Helium Leak Test Unit.
- X-Ray Inspection Units.
- Rod Scanning Unit.
- Rod Inspection and Sorting Unit.
- Rod Decladding Unit.

Assembly Area - In this area, rods are loaded into assemblies and the assemblies are inspected and stored. The functions of the Assembly Area are to receive fuel rods and the required fuel assembly components and to assemble, inspect, and store completed MOX fuel assemblies. The Assembly Area is composed of the following units:

- Assembly Mockup Loading Unit.
- Assembly Mounting Unit.
- Assembly Dry Cleaning Unit.
- Assembly Dimensional Inspection Unit and Assembly Final Inspection Unit.
- Assembly Handling and Storage Unit.
- Assembly Packaging Unit.

In a separate waste area, solid radioactive waste generated during the MOX process is processed, stored, and packaged for shipment. The waste area consists of the following units:

- Filter Dismantling Unit.
- Maintenance and Mechanical Dismantling Unit.
- Waste Storage Unit.
- Waste Nuclear Counting Unit.

A detailed description of the main units is provided in Section 11.2 of the revised CAR.

11.3.1.2 Staff Review of MP Process Safety

11.3.1.2.1 Potential UO_2 Pyrophoricity and Burnback Concerns

MP uses depleted uranium dioxide powder to blend with the plutonium dioxide and to form the matrix for the MOX fuel. Uranium dioxide powders are handled in conventional nuclear fuel fabrication facilities. The staff review noted a potential concern regarding the pyrophoric nature (sometimes referred to as burnback) of some fine uranium dioxide powders that can result in oxidation, damage to equipment (essentially a thermal oxidation effect), and a potential release path due to the damage of confinement and filter systems (Reference 11.3.3.10). This is a known potential concern, as such a rapid oxidation has occurred in NRC licensed facilities. The events involved burnback reactions that started in process equipment and caused localized damage, and then spread through the ventilation system. After these events, relatively large quantities of uranium dioxide powders were found on the filters and equipment (including polycarbonate barriers and filters [prefilters and primary high efficiency particulate air (HEPA) filters]) were damaged. The hot uranium dioxide particles were carried through the ventilation system to the filters, where a combination of the hot particles and continued oxidation reactions damaged the HEPA filters. The health consequences were low due to rapid response by personnel and the relatively low hazard of uranium (i.e., as compared to plutonium).

Burnback reactions evolve heat. A typical reaction is:

$$3\ UO_2 + O_2 \Rightarrow U_3O_8$$

The reaction enthalpy is approximately 75 Kcal/mole U_3O_8 formed at 25° C, using information from standard sources (e.g., References 11.3.3.13 and 11.3.3.16). This equates to approximately 440 joules/g of uranium. Usually, mixtures of oxides (e.g., U_3O_8 and UO_3) are formed and the actual heat release may vary slightly. The heat release may also vary with the specific surface area of the powder. Finely divided uranium dioxide (surface area > 10 m^2/g) can oxidize rapidly at room temperature. Coarser powders undergo oxidation at higher temperatures (e.g., 60° C) and several steps and intermediates may be involved. The burnback phenomena also requires optimal dispersion of a mixture of the particles in air; UO_2 powders in a container or loaded on filters and exposed to air oxidize slowly (i.e., oxidant limited) unless this dispersion occurs. If the powder is too dispersed, no propagation/powder heating occurs and the UO_2 oxidizes slowly (i.e., analogous to a fuel limited condition). The applicant has not provided specific size or surface area information or specifications on the uranium dioxide powder that would be received at the proposed facility. However, the powder would come from an existing fuel fabrication facility using processes and/or equipment that normally produce fine powders for conventional nuclear fuel. Thus, the uranium dioxide powder that would be received at the proposed facility would likely be small in particle size, perhaps with an average diameter in the 1-5 micron range, and susceptible to burnback at room temperature.

The applicant discusses oxidation reactions of uranium dioxide in Section 8.5.1.6.1 of the revised CAR and identifies this as a potential cause for a fire in a glovebox. The applicant also provided additional information on UO_2 powders in response to Requests for Additional Information (RAI) (References 11.3.3.2 and 11.3.3.3) and identified temperature design bases for materials of construction in the facility; the temperature design bases have been reviewed by the staff and found to be acceptable (see revised DSER Section 11.3.1.2.2, below).

Documentation for powder processing areas was reviewed during an in-office review and no PSSCs or design bases were found to address the potential loss of confinement hazard (Reference 11.3.3.11). The applicant provided supplemental information on the subject (Reference 11.3.3.5). The applicant stated UO_2 is processed as a fine powder at low temperatures and within inert atmospheres, and, thus, burnback does not occur during normal operations. The applicant further indicated burnback could occur during off-normal conditions if the inert atmosphere has been replaced by air (the applicant has not currently identified a safety function for the inert atmosphere). The applicant stated burnback has been taken into account in the thermal analysis of the facility during off-normal conditions, and cites the RAI (References 11.3.3.2 and 11.3.3.3) responses. No PSSCs or design bases are identified by the applicant to address loss of confinement concerns caused by burnback. On page 8-26, the revised CAR (Reference 11.3.3.8) does identify the following as additional protective features:

- UO_2 delivered to the facility site and stored in sealed, 30 gallon drums. UO_2 is double-bagged within the drums, under a nitrogen atmosphere.

- UO_2 is maintained in a nitrogen atmosphere throughout the process.

- Fire detection and suppression systems provided for gloveboxes (CO_2 injection) and process rooms (clean agent).

- Use of noncombustible or nonflammable materials for process equipment construction and furnishing.

- Control of combustible materials.

The staff concludes that a potential pyrophoric reaction or burnback of uranium dioxide cannot be dismissed because it has occurred previously during fine UO_2 fuel powder processing and PSSCs have not been identified to address its potential effects upon confinement, such as the entrainment of the (potentially hot) powder into the ventilation system, deposition on filters, and damage to the filters by the hot powder particles and continuing oxidation reactions. This could potentially impact several units in the MP area that handle fine UO_2 powder by itself or blended with plutonium dioxide. Such a burnback event could result in the release of large quantities of uranium oxides (a chemical toxicity concern), the release of plutonium powders from the commingled blend, and/or initiate other loss of confinement events such as fires.

The applicant provided additional information on the filter system (Reference 11.3.3.14). The applicant again acknowledged burnback reactions can occur, but did not expect this to affect the final HEPA filters for the following reasons:

- During normal operations, UO_2 is not expected to be present on the final HEPA filters because the Glovebox and Very High Depressurization Exhaust System (VHD) intermediate HEPA filters prevent any significant quantities of UO_2 powder from reaching the final HEPA filter housing and the high strength roughing and prefilters remove nearly all of the remaining particles before they reach the final HEPA filters. The staff notes that these intermediate filters are not credited in analyses by the applicant and would likely be overwhelmed if a local burnback event were to occur.

- During a fire, UO_2 powder is one of many potential embers. Large embers are removed by the high strength roughing and prefilters. The remaining micron size particles are either cooled by the time they reach the final HEPA filters or do not contain enough energy to degrade the performance of the final filters. The staff notes that the UO_2 powder is likely to start and remain as small particles.

- The energy associated with the burnback phenomena is small when compared to the energies involved in a facility area fire. The process unit containing the largest quantity of UO_2 (520 kg) is the Final Dosing Unit. The energy generated by the oxidation of this quantity of UO_2 corresponds to approximately 50,000 British Thermal Units (BTU). The facility Fire Hazard Analysis (FHA) assumes a combustible loading for this area of 134,701 BTU/ft^2. The unit has an area of about 1,123 ft^2. This yields a total combustible loading of over 151 million BTUs. The quantity of energy released as a result of burnback is negligible when compared to that involved in a process unit fire. The staff has estimated energy releases of 200,000 to 250,000 BTU are possible from oxidation of 520 kg of UO_2. This is larger than the applicant's estimate but still small compared to the FHA loading. However, the staff notes that the main concern with burnback reactions is the challenge to the confinement of the powders, including HEPA filters (Reference 11.3.3.10).

In Attachment 1 of Reference 11.3.3.14, the applicant provides design information on the final HEPA filter and housing design. Key points are:

- All stainless steel ductwork.

- The first stage roughing filter is comprised of stainless steel wire mesh in a stainless steel frame. The filtration efficiency is 60-70% for particles from 3-10 micron in diameter and 10-20% efficient for particles 1-3 micron in diameter.

- The second stage roughing filter is stainless steel wire mesh interwoven with fiberglass. The filtration efficiency is 99% for particles greater than 2 microns in diameter.

- The prefilter is wet laid micro fiberglass, formed corrugation filter media.

- A two stage HEPA filter completes the facility HEPA filter train.

In Attachment 1 of Reference 11.3.3.14, the applicant expects to credit the following engineered features and administrative controls to ensure that the Section 70.61 performance requirements are met:

- high strength stainless steel mesh spark arresters
- high efficiency high strength stainless steel/glass fiber prefilters
- protected two-stage final HEPA filters with structural integrity of greater than 10 inches of water (i.e., pressure drop)
- multiple redundant ventilation fan systems
- ventilation system design ensures adequate air flow dilution
- ventilation system design ensures a pressure drop of less than 10 inches of water across the HEPA filter elements
- preventative maintenance to ensure HEPA filter integrity
- low combustible loads
- fire areas protected by two-hour minimum rated fire barriers

The staff notes that design basis information for particle sizes/removal is not included.

The staff concludes that potential burnback events are not prevented and that fine UO_2 powders and UO_x embers from such events could travel through the ventilation system to the final HEPA filter housing in multi-kilogram quantities. The applicant has not provided sufficient assurance that the metal prefilters will sufficiently remove this powder prior to the HEPA filter elements.

The staff has identified PSSC and design basis information associated with the pyrophoric nature of some UO_2 powders as an open item. This concern applies to all units that could handle UO_2 powders in air. The applicant needs to provide additional design basis information or provide sufficient justification that none are necessary. Staff considers this to be related to the filter soot loading issue discussed in revised DSER Section 7 (Open Item FS-1).

11.3.1.2.2 Potential PuO_2 Heating Effects

The staff has reviewed plutonium handling areas for potential chemical safety concerns. The review noted concerns due to the potential heat generation by the plutonium dioxide; plutonium in the glovebox environment can easily reach equilibrium temperatures of 80^{o}C (Reference 11.3.3.1, Section 2.6.3.1).

Section 8.5.1.6.2 of the revised CAR and an RAI response (References 11.3.3.2 and 11.3.3.3) provide supplementary information on plutonium thermal effects, and provided a summary of the design bases for decay heat and temperatures. The specific heat loads for plutonium were identified by the applicant as:

- Unpolished plutonium: 2.899 W/kg of unpolished PuO_2 powder.
- Polished plutonium: 2.181 W/kg of polished PuO_2 powder.

Using values from the literature (Reference 11.3.3.1), the staff review estimates heat loads of 2.5-3.5 W/kg PuO_2, depending on the isotopic ranges used. These values generally overlap the applicant's heat load estimates. Thus, the applicant values are reasonable.

The applicant identified temperature design bases for materials of construction in the facility; these are reproduced as Tables 11.3-1 and 11.3-2 (References 11.3.3.2 and 11.3.3.3). The response identified the storage rooms, storage gloveboxes, and larger production units as having potentially large heat loads. The applicant's response mentions that the temperature design bases of Tables 11.3-1 and 11.3-2 will be met during normal operations, but might be exceeded during incidents where ventilation is not maintained for the PuO_2 Storage Area and the handling and storage tunnel. Consequently, in Section 5.5.2.1.6.9, the applicant identifies the high depressurization exhaust system (part of the C3 confinement system) as the PSSC with the safety function of providing exhaust so that temperatures in the 3013 cannister storage area are maintained within the design basis values. The staff notes these design basis and approach are consistent with accepted practice for steels (e.g., American Society of Mechanical Engineers [ASME]), concrete (e.g., American Concrete Institute [ACI]), and most plastics (e.g., Reference 11.3.3.12), and finds the approach to be acceptable. Polycarbonate is discussed separately in Section 11.9. The staff finds this approach acceptable for the construction permit stage per the acceptance criteria in Section 8.4.3.5 of the SRP.

Table 11.3-1: Applicant's Design Basis Temperature Criteria

Material	Situation	
	Normal Operating Temperature, C	Hypothetical Maximum Operating Temperature, C
Ordinary Concrete	60	100
Stainless Steel	425	425
BPP #9	80	100
BPP #10	100	100
NS41 Silicone Elastomer	180	180
Polycarbonate (Lexan)	35 (thermal cycling) 50	70
BPP = Borated Polyethylene Plaster		

Table 11.3-2: Applicant's Additional Temperature Design Basis Criteria for Personnel Protection

Material	Normal Operating Temperature Limit, ^{o}C
Borate (colemanite) concrete	80
Kyowaglas - storage - operating	80 35
Fuel rods, pellets, and cladding	60

11.3.1.2.3 Potential PuO_2 Pyrophoricity and Burnback Concerns

The AP process produces plutonium (IV) oxalate, which generally requires a higher calcination temperature (about 400°-500° C) than either plutonium (III) or plutonium (VI) oxalates (about 200°C). The staff found that plutonium dioxide powder from the calciner in the Oxalic Precipitation and Oxidation Unit does not have a design basis or specification, and the calcining operation does not have a design basis related to plutonium dioxide quality. The staff concerns fall into two areas:

- Oxidation reactions and powder dispersion due to the presence of substoichiometric oxides of PuO_2 (essentially PuO_{2}-$_x$) that are ignited by the decay heat. Depending on conditions, plutonium can form varying oxides, some of which can be pyrophoric. In general, plutonium oxides with oxygen contents lower than the dioxide are potentially pyrophoric (Reference 11.3.3.1, Section 2.6.3.2).

- The presence of water or other volatile species and impurities that can increase pressure inside containers due to radiolysis and decay heat, and, ultimately, cause overpressurization resulting in an explosion and a loss of confinement.

The applicant discusses plutonium dioxide pyrophoricity in Section 8.5.1.6.2 of the revised CAR. This states PuO_2 supplied to the facility will meet the requirements of Department of Energy (DOE)-STD-3013-2000 in order to ensure stability. For PuO_2 within the facility, a standard or specification is not identified. Supplemental information provided by the applicant (Reference 11.3.3.5) stated that PuO_2 is stable in air. The applicant states the formation of sub-stoichiometric oxides is not a concern as reduction of the plutonium (IV) oxalate does not occur. The staff notes oxide formation depends on the process conditions, and, without a specification or basis, some sub-stoichiometric plutonium dioxide from impurity reactions cannot be discounted. The powder will also be handled under a nitrogen atmosphere, but this is not identified as a PSSC.

The staff conducted a brief literature review and found that PuO_2 is often present as a substoichiometric oxide (i.e., PuO_{2}-$_x$) and prone to absorb moisture unless it has been calcined and held at a temperature of about 900°C for two hours to stabilize (ceramicize) the material (Reference 11.3.3.1, Section 2.7). Unstabilized plutonium oxides may exhibit pyrophoric reactions in air, due to its substoichiometry or the radiolysis of absorbed water, which could lead to a loss of confinement and release or initiate other events, such as fires.

DOE experience with PuO_2 indicates the pyrophoricity and stability (including entrained, attached, and absorbed compounds, such as water) of PuO_2 depend on the calcination conditions (e.g., time, temperature, and atmosphere) and that substoichiometric and unstable PuO_2 can initiate events (Reference 11.3.3.13). The staff review indicates a lower calcination temperature may be involved at the facility, and standards and limits may be needed to control PuO_2 substoichiometry and instability. The staff has not found standards, limits etc. described by the applicant that will assure that the formation of significant amounts of sub-stoichiometric or unstable PuO_2 (from the calciner and in MP operations) is prevented.

The applicant has identified nominal values of humidity (water) in the powders entering the MP area; for PuO_2, 1% is used for normal situations and 3% is used for off-normal situations. These are not identified as design bases and PSSCs are not specified. The DOE 3013 standard mentions a loss on ignition of 0.5% (i.e., weight loss from water vaporizing due to heating of the material). Moderation (i.e., water content) is not controlled by the applicant in the calciner, homogenization, and MP buffer storage units. Water and volatile content have not been identified as design bases.

Furthermore, at the February 13, 2002, public meeting, the applicant stated that a review was underway to determine if unstabilized PuO_2 would be received by the facility. The staff review of the calcining section of the AP process (see revised DSER Section 11.2) did not identify any PSSCs or design bases for ensuring that stabilized PuO_2 powder would be produced. At the December 10-12, 2002 Public Meeting, the applicant indicated the PuO_2 storage containers would be convenience cans, with gas vent filters and spring-loaded tops for pressure relief. These are not identified as PSSCs.

The applicant has subsequently submitted additional information on the subject (References 11.3.3.11 and 11.3.3.14). Leakage from the can is covered by the spill event discussed in revised CAR Section 5.5.2.3.6.4 (Load Handling Controls - C4 Confinement). For pressure accumulation within the can, the lid is deterministically assumed to impact the glovebox. The Material Handling Control PSSC is used to mitigate this potential event. For this case, this PSSC may include control of moisture content of the material, residence time of the canned material (e.g., in the range of months and years), and/or design pressure of the reusable can. The specific items relied on for safety (IROFS) will be determined as part of the integrated safety analysis (ISA).

In addition, the applicant indicates over-pressurization from the oxidation of plutonium (III) oxalate contained within the stored cans may be prevented through one of the following:

1. Controls on plutonium oxalate furnace (calciner) parameters, such as residence time and minimum temperature to ensure complete oxidation and moisture content of plutonium oxalate entering the furnace.
2. Experimental confirmation of the minimum water content accompanying plutonium (III) at the exit of the furnace to prevent any over-pressurization due to the energy liberated during re-oxidation (to plutonium (IV)).
3. Measurement of the plutonium (III) content in the plutonium dioxide powder.

The specific IROFS will be identified as part of the ISA.

The staff review found that leakage or spillage from the can that does not challenge confinement is adequately addressed by the C4 confinement system, as discussed in revised CAR Section 5.5.2.3.6.4. For the case with pressure accumulation, the Material Handling Control PSSC has the safety function to prevent impacts to the glovebox from two types of events; over-pressurization from residual volatile species (and their radiolysis) and over-pressurization from the oxidation of plutonium (III). The description of the Material Handling Control PSSC in revised CAR Section 5.6.2.3 does not mention any design bases. The staff notes that the applicant appears to be considering both preventative and mitigative approaches for over-pressurization events.

The applicant provided supplemental information on this subject (Reference 11.3.3.17). This identifies an additional safety function of the Material Handling Controls PSSC to prevent potential over-pressurization of the reusable plutonium dioxide cans, due to radiolysis or oxidation of plutonium (III) oxalate, and its subsequent impact to the glovebox. The associated design basis is to ensure that the reusable can is designed to the maximum internal pressure calculated for these events, plus an additional 10% as the margin. The staff notes this provides an approach with a defined margin, and is consistent with the safety approach for fluid transport system components, as discussed in revised DSER Section 11.8. The staff finds this acceptable for the construction permit stage.

11.3.1.2.4 Sintering Furnace Concerns

The staff requested clarification and more information on the controls around the sintering furnaces, including the hydrogen detectors, as this appears to involve a complex mixture of hydrogen detectors, oxygen sensors, and pressure controls. In response (References 11.3.3.2 and 11.3.3.3), the applicant provided a diagram that showed part of the intended control range of hydrogen in argon was flammable in air and stated that the sensors would detect hydrogen and, at 25 percent of the lower flammability limit (LFL), would terminate hydrogen flow at the hydrogen/argon mixing station. In addition, fire detector(s) in the room would detect any fire and alarm, but would not terminate hydrogen flow. DCS has not completed the detailed design of the system. DCS explained that the sintering furnace would not be in a glovebox and the room functioned as secondary confinement; the sintering room and the furnace would become the PSSCs for confinement (References 11.3.3.2 and 11.3.3.3).

The sintering furnace has water-cooled walls and a moisture conditioning system for the furnace gases (the hydrogen/argon mixture). The in-office review of the preliminary hazard analysis (PHA) and preliminary accident analysis (PAA) did not find a potential steam explosion included (Reference 11.3.3.11). The applicant provided supplemental information on potential steam explosions (Reference 11.3.3.5). The applicant states steam explosions have been identified during the facility safety analysis as a credible event. Ongoing safety analyses by the applicant have identified three types of scenarios that can lead to a steam explosion: entry of water from the water cooling loop, entry of water from the humidifying loop, and steam generation within the water cooling systems. The applicant mentions that a steam explosion involving a water-cooled furnace has previously occurred at Los Alamos National Laboratory (LANL), but this involved internal cooling coils while the proposed furnaces would have external cooling coils. The applicant further states that a cooling water leak will be demonstrated to be highly unlikely, specific items relied on for safety features will be identified for the humidifying loop, and relief valves will render steam pressurization of the cooling water loop to be highly unlikely. Supporting information to demonstrate an even frequency of highly unlikely is not included in the response.

The staff reviewed Sections 5.5.2.4.6.2 and 11.2.2.16 of the revised CAR for additional information. These sections identify a prevention strategy to address potential steam explosions. The PSSC is the process safety control subsystem with the safety function of isolation of humidifier water flow on high water level. Thus, the water supply to the humidifier would be terminated prior to the humidifier overflowing and potentially allowing liquid water to enter the sintering furnace via the gas supply side. This would be an active, engineered control. The staff concludes that such an active engineered control could be designed and implemented to prevent a steam explosion, and finds it acceptable. Sections 11.2.2.16 and 11.4.11.8 identify an additional function of the process safety control subsystem to shut down the sintering furnace (by electrical cut-off) upon loss of cooling water flow, and to shut down zone heating if the related surface temperature is excessive (over 60° C - this is identified as the design basis). There is also a backup cooling water supply and the cooling water coils are on the outside of the furnace. The staff reviewed preliminary view and section drawings of the sintering furnace during an in-office review and concluded that: the coils are outside the sintering furnace shell, the shell is thicker than the cooling water tube thickness, and the coils are not confined within additional metal shells. The staff concludes that a steam explosion from a cooling water leak is either unlikely or highly unlikely, and, if it were to occur, unlikely to penetrate the significantly thicker sintering furnace shell (i.e., if the event were to occur at all, it would be directed towards the unconfined areas which are the opposite direction from the furnace itself). Thus, a potential cooling water leak resulting in a loss of confinement from a steam explosion would be highly unlikely. The staff finds that the applicant's approach for addressing steam explosions is acceptable per SRP 8.4.3.5.

DCS had not performed any coverage or location/distance analyses for sensors and detectors. DCS stated they would verify that a hydrogen leak from the furnace would be detected and terminated by pressure detection. DCS expected that, between the H_2 monitors and pressure sensors, a H_2 leak would be detected and flow terminated (Reference 11.3.3.4 and 11.3.3.11).

The revised CAR identifies design bases for instrument and control PSSCs in Section 11.6.7. This states combustible and hydrogen detectors will be selected in accordance with ISA-12.13-Part I-1995, "Performance Requirements for Combustible Gas Detectors." Installation, operation, and maintenance of combustible gas detectors would be in accordance with ISA RP12.13-Part II-1987, "Installation, Operation, and Maintenance of Combustible Gas Detection Equipment." The staff has reviewed these standards for applicability; they include considerations of gas properties, sources, and detector locations. A setpoint methodology is also included, based upon ANSI/ISA-67.04.01-2000, "Setpoints for Nuclear Safety-Related Instrumentation." This is a standard approach for the nuclear industry. The staff concludes that the design bases for hydrogen detection have been adequately described for the construction authorization stage.

The applicant indicated hydrogen sensors in the room would detect any leaks and would terminate the flow of hydrogen flow to the furnace. In addition, pressure controls would detect any loss of pressure in the furnace due to a leak and also terminate the hydrogen flow (Reference 11.3.3.11). The staff expressed concerns about the potential for small leaks to result in hydrogen burning that might go undetected and exacerbate radionuclide releases. Regarding the airlocks, the applicant stated there would be interlocks to prevent both doors (inner and outer) from opening at the same time. In addition, hydrogen sensors in the airlocks and oxygen sensors in the furnace would detect their respective gases and terminate the hydrogen flow; all of these would be PSSCs.

The applicant provided supplemental information on PSSCs and design bases in the sintering furnace area which identified additional PSSCs and design bases (Reference 11.3.3.6). In addition, Section 11.2.2.16 of the revised CAR states that, if hydrogen is detected in the furnace room, then the gas supply is automatically shifted to pure argon (i.e., the hydrogen flow is terminated). In Section 5.5.2.4.6.1, the Revised CAR discusses a prevention strategy for hydrogen explosions. The PSSC is identified as the Process Safety Control Subsystem, with the safety function of preventing the formation of an explosive mixture of hydrogen within the facility associated with the use of the hydrogen-argon mixture. The revised CAR indicates the applicant is performing detailed analyses of the hydrogen-argon system and associated furnace design and operations as part of the final design and ISA. The revised CAR notes that potential specific controls for preventing hydrogen explosions around the sintering furnace (such as limiting the hydrogen content in the hydrogen-argon mixture, monitoring for oxygen within the furnace, monitoring for hydrogen outside of the furnace, and crediting dilution air flow associated with the

High Depressurization Exhaust System (HDE) or VHD systems) have already been identified as PSSCs in other safety strategies and, thus, there would be little or no impact of the specific control selection upon design at the ISA stage. The staff finds the proposed approach to be an acceptable strategy for preventing explosions around the sintering furnace. The staff concludes that combinations of the specific controls already identified as PSSCs should be capable of performing the safety function of preventing explosive mixtures. The staff notes that a specific approach based upon limiting the hydrogen content in the hydrogen-argon mixture may be the simplest and most effective approach.

In Section 8.5.1.1.1, the revised CAR states the hydrogen design basis is 50% of the LFL of hydrogen in air. This value will not be exceeded during normal and off-normal conditions. The LFL is considered the safety limit, while 25% of the LFL is considered the expected setpoint at which necessary control actions are initiated during normal operations. Actual setpoints will be determined during final design.

The applicant has provided a methodology for LFL determination. This is discussed in Section 11.2 of the revised DSER.

The staff review indicates 25% of the LFL in a chemical flow system is normally considered a hydrogen limit analogous to a design basis (Reference 11.3.3.18). Other NRC licensed fuel fabrication facilities typically use 25% of the LFL as an administrative limit. The SRS waste storage tank facilities alarm at 10% but use 25% of the LFL as their design basis (Reference 11.3.3.18). The staff concludes that a 25% of the LFL value is usually used as a design basis or equivalent value in similar nuclear facility applications. The staff has not received adequate justification from the applicant for the higher, 50% of the LFL design basis value that addresses the difference and incorporates uncertainties and sensitivities. This design basis value is identified as an open item (Open Item AP-2).

11.3.1.2.5 Design Basis of the PSSCs and Applicable Baseline Design Criteria

The design bases of MP associated with chemical processing have been discussed in Sections 11.3.1.2.1 to 11.3.1.2.4.

The applicant has stated the BDC specified in 10 CFR 70.64(a) are incorporated into the design and operation of the facility (revised CAR Section 5.5.5.4). The applicant states information demonstrating compliance with these criteria is provided in the applicable chapters of the revised CAR. For chemical protection, 70.64(a)(5) states:

> *"Chemical protection. The design must provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from licensed material."*

Chapter 8 of the SRP contains guidance and references to other peer reviewed work on the subject of chemical safety. To date, the applicant has not provided sufficient information to meet the requirements of 10 CFR 70.64(a)(5).   The staff review using the SRP has identified open items and the staff concludes the applicant has not satisfied this BDC.

Related to chemical protection, the explosion protection BDC is stated as part of the fire protection BDC in 70.64(a)(3):

“Fire protection. The design must provide for adequate protection against fires and explosions.”

Chapters 7 and 8 of the SRP describes the fire protection/explosion BDC and include guidance and references to other peer reviewed work on the subject. As discussed in Chapters 7, 8, 11.2, and 11.3, the staff review, using the SRP, has identified open items with respect to fire and explosions and the staff concludes the applicant has not satisfied this BDC.

11.3.2 EVALUATION FINDINGS

In Section 11.3.7 of the revised CAR, DCS provided design basis information for the MP process that it identified as PSSCs for the facility. Based on that the staff’s review of the revised CAR and supporting information provided by the applicant relevant to the AP process, the staff finds that, due to the open items discussed above and listed below, DCS has not met the BDC set forth in 10 CFR 70.64(a)(3), for explosions, and (a)(5), for chemical safety. Further, until the open items are closed, the staff cannot conclude, pursuant to 10 CFR 70.23(b), that the design bases of the PSSCs identified by the applicant will provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

The following item remains open:

- PSSC and design basis information associated with the pyrophoric nature of some UO_2 powders (revised DSER Section 11.3.1.2.1) (MP-1). This is related to the filter soot loading issue identified as FS-1 in revised DSER Section 7.

The following open items in the April 30, 2002, draft Safety Evaluation Report, have been closed: MP-2, MP-3, and MP-4. See Appendix B.

11.3.3 REFERENCES

11.3.3.1 Department of Energy (U.S.) (DOE). DOE Std 1128-98, “Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities.” DOE: Washington, D.C. June 1, 1998.

11.3.3.2 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Response to Request for Additional Information, August 31, 2001.

11.3.3.3 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Requests for Additional Information, Clarifications, and Open Item Mapping into the Construction Authorization Request Revision (DCS-NRC-000120), November 22, 2002.

11.3.3.4 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, January 7, 2002.

11.3.3.5 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission RE Clarification of Responses to NRC Request for Additional Information, DCS-NRC-000083, February 11, 2002.

11.3.3.6 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, March 8, 2002.

11.3.3.7 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, April 23, 2002.

11.3.3.8 Ihde, R., Duke Cogema Stone & Webster, letter to W. Kane, U.S. Nuclear Regulatory Commission, RE Mixed Oxide Fuel Fabrication Facility—Construction Authorization Request, October 31, 2002.

11.3.3.9 Nuclear Regulatory Commission (U.S.) (NRC). NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility." NRC: Washington, D.C. August 2000.

11.3.3.10 Nuclear Regulatory Commission (U.S.)(NRC), Washington, D.C. Information Notice 92-14, "Uranium Oxide Fires at Fuel Cycle Facilities." NRC: Washington, D.C. February 21, 1992.

11.3.3.11 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to E.J. Leeds, NRC, RE November 27-29, 2001 In-Office Review Summary of DCS Construction Authorization Request Supporting Documents for the MFFF, December 18, 2001.

11.3.3.12 *Perry's Chemical Engineers' Handbook*, Seventh Edition, McGraw-Hill, New York 1997.

11.3.3.13 DOE 3013 Standard: Department of Energy (U.S.) (DOE) DOE STD 3013-2000, "Stabilization, Packaging, and Storage of Plutonium-Bearing Materials." DOE: Washington, D.C. November 1999.

11.3.3.14 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Mixed Oxide (MOX) Fuel Fabrication Facility Construction Authorization Request Change Pages, February 18, 2003.

11.3.3.15 E.H.P. Cordfunke, *The Chemistry of Uranium (Including its Applications in Nuclear Technology)*, Elsevier, New York (1969).

11.3.3.16 D.T. Hobbs, "Possible Explosive Compounds in the Savannah River Site Waste Tank Farm Facilities," WSRC-TR-91-444, Revision 3, February 15, 2000.

11.3.3.17 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Mixed Oxide (MOX) Fuel Fabrication Facility Construction Authorization Request ,DCS-NRC-000129, February 18, 2003(DCS-NRC-000131), April 1, 2003.

11.3.3.18 Pierson, R., U.S. Nuclear Regulatory Commission (NRC), memorandum to D. Clark Gibbs, U.S. Department of Energy (DOE), RE Estimates of Hydrogen Generation from Wastes at the Proposed TWRS-P Facility, April 21, 1999.

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